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RESEARCH ARTICLE

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Assessing the distribution pattern of otters in four rivers of the Indian Himalayan biodiversity hotspot

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Abstract

1. The Eurasian otter (*Lutra lutra*), smooth-coated otter (*Lutrogale perspicillata*), and Asian small-clawed otter (*Aonyx cinereus*) have all been reported previously from the Indian state of Uttarakhand. However, little information is available about their current distribution in a mountainous region that is subject to increasing human-induced stressors (such as hydropower plants, pollution, sand and boulder mining, destructive fishing techniques, poaching).
2. Owing to important roles played by these otters in structuring riverine food webs (particularly taking account of their roles as top carnivores), it is critical that they receive suitable protection in the face of projected temperature rise, change in precipitation patterns, and associated river flows in this Himalayan biodiversity hotspot. This study assesses otter distribution in four rivers of Uttarakhand as a basis for informing future conservation actions.
3. Field surveys were conducted (October 2018–January 2019) in reaches of the Kosi, Ramganga, Khoh, and Song rivers, supported by semi-structured interviews (N = 379) conducted with members of local communities to collect qualitative data on views and perceptions of otter species. In addition, community-based otter awareness camps were organized for local youths (N = 105), adults (N = 115), and schoolchildren (N = 256 covering 10 schools).
4. Habitat suitability maps were created using remote-sensing data, survey findings, and a geographic information system to provide information about priority reaches of river to be targeted for future conservation efforts.
5. This study provides critical interdisciplinary baseline information to guide decision-makers towards developing a targeted, otter-specific conservation programme for this important Himalayan biodiversity hotspot.
6. The otter conservation education programmes conducted during this study resulted in a proposal to set up a community-based conservation initiative to monitor and report otter sightings from the area, potentially representing a way forward for achieving simultaneous otter conservation and associated ecosystem benefits for local communities.

KEYWORDS
climate change, freshwater, human-induced stressors, Lutrinae, Mustelidae, otters, Uttarakhand, wetlands

1 | INTRODUCTION

Species conservation in the Indian Himalayan region (IHR) has often focused on megafauna. The Bengal tiger (*Panthera tigris tigris*), snow leopard (*Panthera uncia*), Indian elephant (*Elephas maximus indicus*), and the greater one-horned rhinoceros (*Rhinoceros unicornis*) are afforded the highest legislative protection and are often the prime recipients of conservation attention. By contrast, a lesser degree of explicit attention is devoted to otter conservation, despite these animals being regarded as 'ambassadors of wetlands' (Gupta, Johnson, Sivakumar, & Mathur, 2016). This is in spite of a variety of legislation requiring decision-makers to pay conservation attention to otters, particularly where they occur within the legislative boundaries of protected areas (national parks, wildlife sanctuaries, and community and conservation reserves; Gupta et al., 2016).

A previous review of available information found that there have been observations of otters in rivers of the IHR in the past decade (Gupta et al., 2016). Three species of otters have been previously reported from Uttarakhand, based on observations in the wild, visual signs, discussion with communities, and unconfirmed reports (Hussain, 1999; Hussain, Gupta, & de Silva, 2011; Khan, Dimri, Nawab, Ilyas, & Gautam, 2014; Nawab & Hussain, 2012a). These three species are the Eurasian otter (*Lutra lutra*), smooth-coated otter (*Lutrogale perspicillata*), and Asian small-clawed otter (*Aonyx cinereus*). However, there is little available information about their current distribution in the face of increasing human-induced stressors (hydropower plants, pollution, sand and boulder mining) and changing climatic variables, including a projected rise in temperature and changes in precipitation patterns and river flows in Uttarakhand (Alfthan et al., 2018; Indian Network for Climate Change Assessment, 2010; Shrestha et al., 2015). It is critical, therefore, that the distribution of otter species is determined as a key input to otter-specific as well as more general river conservation strategies, as these top carnivores play important roles in structuring riverine food webs (Gupta et al., 2016).

1.1 | Otters of Uttarakhand

The conservation status of the three species of otters previously reported from Uttarakhand are outlined in the following.

The Eurasian otter is classified as Near Threatened on the IUCN Red List, based on declines in the Asian population attributed to the sensitivity of the species to the recent intensification of human-induced threats (Roos, Loy, de Silva, Hajkova, & Zemanová, 2015). The Eurasian otter is listed on Appendix I of CITES, Appendix II of the Bern Convention, and Annexes II and IV of the European Habitats Directive (Council of the European Communities, 1992; Roos et al., 2015). It is also listed as an endangered species in India and is protected on Schedule II (Part 2) of the Wildlife (Protection) Act, 1972.

The smooth-coated otter is classified as Vulnerable on the IUCN Red List, based on an inferred population decline resulting from habitat loss and exploitation (de Silva et al., 2015). Since 1977, the smooth-coated otter has been listed on Appendix I of CITES. It is a protected species in almost all the countries in its range, which prohibits its killing (de Silva et al., 2015). In India, it is protected on Schedule II (Part 2) of the Wildlife (Protection) Act, 1972.

The Asian small-clawed otter is also classified as Vulnerable on the IUCN Red List, based on an inferred past population decline attributed to habitat loss and exploitation (Wright, de Silva, Chan, & Reza Lubis, 2015). Potential threats to the survival of Asian small-clawed otters throughout Asia include destruction or degradation of essential habitat resulting from changing land-use patterns and other development activities (Wright et al., 2015). In India, the primary threats are loss of habitat from tea and coffee plantations in the hills, loss of mangroves in the coastal areas driven by aquaculture and increased human settlements, and siltation of smaller hill streams caused by deforestation (Wright et al., 2015). The threat posed by poaching is still very significant in many parts of India, and across Southeast Asia, and requires constant monitoring (Wright et al., 2015). Since 1977, the Asian small-clawed otter has also been listed on CITES Appendix I. In India, the species is protected on Schedule I of the Wildlife (Protection) Act, 1972.

Threats faced by these three otter species are similar at the local level. Poaching is suggested as a principal cause of the decline of otter species in South and Southeast Asia, and possibly also in North Asia (Savage & Shrestha, 2018). Despite conservation legislation, trade in these animals continues, principally for their pelt (most seizures of big cat products are accompanied by otter skins). In 2005, there were six seizures of otter skins in Uttarakhand and another six seizures of otter skins from the neighbouring Indian state of Uttar Pradesh (Savage & Shrestha, 2018). A major wildlife seizure in Delhi in November 2009 comprising 30 kg of tiger bones, two tiger skins, and two leopard skins also included seven otter skins (Times of India, 2009). These seized cargos almost certainly underrepresent substantially the scale of poaching and animal trade (Gomez, Leupen, Theng, Fernandez, & Savage, 2016; Savage & Shrestha, 2018). Uttarakhand state, on the border with Nepal, has a central position on the northward route of traded wildlife, and is also a likely source of otter skins. In addition, Uttarakhand has a very high human population density and is also sensitive to climate change (Alfthan et al., 2018; Shrestha et al., 2015). All of these human-induced and climate-vectored influences are likely to have an adverse impact on otter populations in the region.

All three of these otter species are top carnivores, playing critical roles in the balance and processes of ecosystems, significantly influencing the overall spatiotemporal dynamics of river systems, and thus the beneficial ecosystem services that they provide (Gupta et al., 2016). Otters should, therefore, constitute an integral part of any wetland conservation programme in India and beyond.

As their elusive nature means that they are rarely encountered during daytime surveys, there has been a growing concern among ecologists and conservationists in Uttarakhand regarding presence or possible absence of the three otter species, and particularly outside the boundaries of protected areas (Corbett and Rajaji Tiger Reserves). Insufficient attention has been given to understanding how increasing human-induced stressors and projected climate change in Uttarakhand may have affected the distribution of these top predators. This study assessed otter distribution in four rivers in Uttarakhand, developing habitat suitability maps for use in future conservation actions, particularly outside protected areas. An additional objective was to evaluate possible species-specific targeted actions for the immediate protection of otters and their long-term conservation.

2 | STUDY AREA

The study focused on four rivers in the Indian state of Uttarakhand (30.0668°N, 79.0193°E), located in the western region of the Indian Himalayas. Uttarakhand is endowed with rich biodiversity with numerous rivers, reservoirs, freshwater lakes, and wetlands (Gupta, Sivakumar, Mathur, & Chadwick, 2015). The Kosi River rises in Budha Peenath village in the Kausani area of Almora District of Uttarakhand and has a total length of ~240 km with a catchment area of 3,420 km^2. The Western Ramganga River is an important tributary of the Ganges River, originating in the Shivalik Himalayas at Dudhatoli in Chamoli District of Uttarakhand. The Khoh River is a tributary of the Western Ramganga, originating in Langur in Dwarikhal with a catchment area of >250 km^2. The Song River is a tributary of the Suswa River, which is in turn a tributary of the Ganges, and originates as a spring-fed stream in the southern slopes of the Mussoorie ridge in the Himalayan range (Gupta et al., 2015; Figure 1).

3 | METHODS

Field surveys were conducted on foot by survey teams along the banks of the rivers (Kosi, Ramganga, Khoh, and Song) to collect evidence of otters. These rivers are recognized as some of the last bastions of otter populations in Uttarakhand.

Otters defaecate on prominent structures, such as rocks, tree trunks, islands, and river banks, and these droppings, known as spraints, can be easily observed in the field. Otter tracks are also clearly visible on sandy banks and in muddy sites along rivers. Otter latrines (discrete sites where otters regularly deposit spraints, urine, and anal secretions) are also prominent, and their dens, although rarely seen, are also important signs of otter presence. Fieldwork was conducted pre- and post-monsoon, and in the winter months of 2018 and 2019. Conditions during the monsoon season can wash

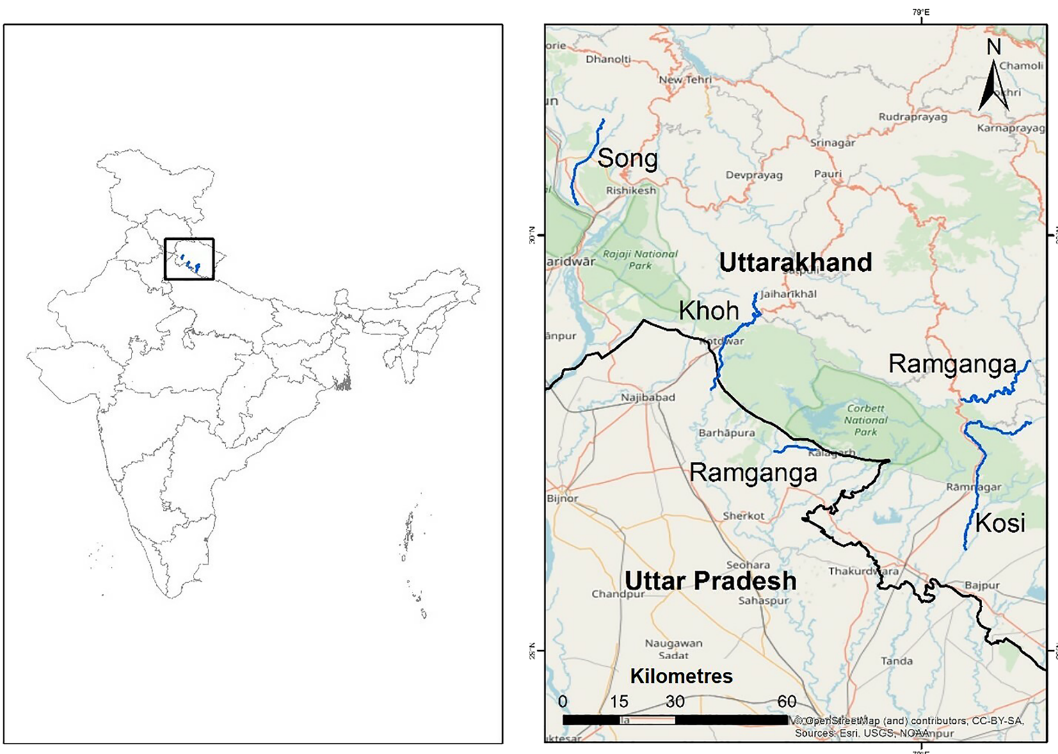

FIGURE 1 A map showing the study areas of the Kosi, Ramganga, Khoh, and Song rivers in Uttarakhand, India

away indirect signs of otters, such as spraints, tracks, dens, and latrines, and can also make access to survey sites challenging or hazardous. The post-monsoon sampling season is favourable, as declining water levels expose muddy banks, enabling more frequent recording of otter tracks. Otter surveys were conducted between 8:00 a.m. and 5:00 p.m. in order to avoid adverse interactions with wildlife in the study sites, following learning from an initial scoping study in 2018.

3.1 | Otter survey

The otter survey method followed Anoop and Hussain (2004) and Nawab and Hussain (2012a). Each of the selected rivers was divided using a geographic information system into minimum otter home ranges common to all three species (Hussain & Choudhury, 1997). Data on otter signs (spraints, tracks, dens, and grooming sites) were recorded in 400 m stretches. Teams comprising four researchers conducted the survey, walking along both river banks and searching for otter signs. In each survey section, important habitat variables (bankside condition, water current and depth, bank slope, escape cover distance, basking and grooming sites, vegetation, dead logs, sandy islands, and braided channels) were recorded where present. Further environmental parameters and disturbance were also recorded where considered potentially important for otters (Anoop & Hussain, 2004), and any opportunistic observations of otters during the course of the survey were also recorded and their position noted. The locations of tracks, spraints, and other indirect and direct signs were recorded using a global positioning system. Surveying indirect signs of otters was very important, as these species are elusive and either nocturnal or crepuscular (Hussain, 1999; Hussain et al., 2011; Khan et al., 2014; Nawab & Hussain, 2012b).

3.2 | Social science surveys

Social science surveys were conducted using a semi-structured interview approach (Gupta, Sivakumar, Mathur, & Chadwick, 2014). Their aim was to document local community knowledge, attitudes and perceptions regarding otters, including questions such as: Have otters been present in the past in your area? Are otters present in your area now? Have otter numbers here been increasing, decreasing, stable, or not known? Are any factors perceived as threatening the otter population? The respondents were from communities located along the four selected rivers. As many households as possible were approached for the survey, seeking responses from both men and women, to ensure that a significant number of individual responses were obtained for the analysis.

Community selection was based on the voluntary willingness and the availability of members in the study area during the field surveys. Consent was requested and obtained from all the participants to make notes of the conversations. All responses were kept anonymous so that respondents felt free to express their views (Everard et al., 2019).

3.3 | Otter conservation education programmes

A number of otter conservation education programmes were also conducted to promote awareness about the importance of otters as top carnivores in river ecology. These were delivered through informal talks with local people, forest managers, and nature guides; presentations and education programmes at community groups and in schools; and by putting up posters and distributing leaflets. These education programmes were conducted after the questionnaire surveys to avoid influencing respondents' answers.

3.4 | Habitat suitability mapping for otters

Habitat suitability mapping was achieved by the integration of remotely sensed data. The satellite data sets used in this study were from Sentinel 1 (synthetic aperture radar) VV polarization band, Sentinel 2 (multispectral) bands B1–B8, B8A, B9, B11, and B12, and Shuttle Radar Topography Mission (SRTM) topographic data (see Supporting Information).

Habitat suitability mapping was divided into two parts:

1. Derivation of a land use land cover (LULC) map. The data sets from different sensors (Sentinel 1, Sentinel 2, SRTM) have unique characteristics. These data sets were co-registered to produce a layer stack (Schmitt, Hughes, & Zhu, 2018). 'Random forest', a machine-learning technique, was used for classification, from which the LULC map was produced (Gislason, Benediktsson, & Sveinsson, 2006). In total, 70% of ground control points were used for training the classifier, and the remaining 30% of ground control points were used for validation. The classified map was subjected to accuracy assessment using statistical methods.
2. Habitat suitability mapping. Mapping suitable areas for otters was achieved by applying a weighted linear modelling approach (Malczewski, 2011) in ArcGIS 10.1 (Environmental Systems Research Institute, 2012). A weighted linear combination is the most prevalent procedure for multicriteria evaluation, in which factors (e.g. variables) are combined together by applying a weight to each. The presence of otters has been strongly related to various features of land cover and protected reaches of rivers, and negatively correlated with elevation (Barbosa, Real, Olivero, & Vargas, 2003; Jo, Won, Fritts, Wallace, & Baccus, 2017; Robitaille & Laurence, 2002; Romanowski, Brzeziński, & Żmihorski, 2013) (see Supporting Information). Four primitive attributes were selected as a basis for development of the habitat suitability mapping: land cover; elevation range; slope; and distance from the river. Equal weighting of these factors was applied in the model as all were equally important for habitat suitability mapping. The output of this combined approach was an otter habitat suitability map; the final product was a habitat suitability index (HSI), semi-quantitatively representing the capacity of an area to fulfil the requirements of the study species.

The linear model depicted in Equation (1) was used to derive the habitat suitability map, identifying four classes: high suitability (s = 1); moderate suitability (s = 0.75); low suitability (s = 0.50); and unsuitable (s = 0.25).

$$\text{F suitable} = 0.25(\text{LULC map}) + 0.25(\text{Slope}) + 0.25(\text{Elevation}) + 0.25(\text{Distance from river}) \quad (1)$$

The linear model used binary values for each primitive attribute, converting it to a binary image (0 and 1). HIS = 1 represents areas where conditions depicted were satisfied for each primitive, and HIS = 0 represents areas where the conditions were not satisfied for all of the primitives. The model was then applied to derive suitable maps.

4 | RESULTS

4.1 | Current distribution of otters in the four rivers of Uttarakhand

Otter tracks and dens were recorded from the banks of the Ramganga River, and otter tracks and a latrine were recorded from the banks of the Kosi and Khoh rivers (Figure 2). These were identified as smooth-coated otter signs (N. Duplaix, personal communication, February 2019). Direct sightings of smooth-coated otters were also made on the Ramganga (bordering the Corbett Tiger Reserve) and Khoh rivers (bordering the forest boundary) (Figure 3). The study showed that the distribution of smooth-coated otters along three of the four rivers examined is patchy and largely restricted to a small subset of reaches (Table 1).

FIGURE 2 Otter tracks

Otter signs were found at 26.6% of sites from all four rivers surveyed. Most of the positive sites (45%) were found on rocky banks, followed by sandy banks (40%), clay banks (9%), and banks with shoreline vegetation and marsh (6%), indicating greater preference for rocky banks. This may result from the higher availability of den sites in rocky terrains (Hussain & Choudhury, 1997), although rocky banks may have more marking locations available compared with sandy or clay banks. During the survey, seven otters were sighted in two different groups, each consisting of three or four animals. No evidence of pups was recorded. No direct (visual) or indirect sightings of the Eurasian or small-clawed otters were recorded from any of the study sites. No direct or indirect signs of smooth-coated otters were recorded from the Song River.

It is important to note the limitations imposed upon this survey, as the study sites were dynamic systems, with species occurrence and detection constrained by season and time of the day owing to variation in activity levels and behaviour among species. Otter species may also have been underrecorded as they are highly sensitive to disturbance, including by the presence of surveyors. Therefore, the sightings and signs were pooled for each surveyed river during completed surveys, aggregating reported encounter rates of species for entire rivers.

4.2 | Social science surveys

In total, 279 semi-structured interviews were conducted during the survey period among villages along surveyed rivers. Interviewed participants comprised 204 male and 75 female local community members, aged between 18 and 70 years old. Respondents were shown photographs of otters, and 20% reported not having seen otters in the preceding 5 years during their day-to-day activities along the rivers. Sixty per cent of respondents mentioned that, although they had not directly seen otters, they knew someone from the area who had, or else that they had seen indirect signs of otters. They said that this could either be because the animals are shy or that they are not present in as large a number as they had been more than a decade ago. The remaining 20% of the respondents had seen otters in the wild, either in the rivers during dusk or along the banks during dawn.

Interestingly, 40% of respondents mentioned that, although not aware of any cultural or religious associations with otters, they believed that killing any living species will bring bad luck. Fifty-five per cent of the respondents said that it was likely that otters have some importance, but they were not aware of their exact function. Ninety per cent of the respondents reported that there had been a sharp increase in human-induced stressors in the area, which could affect otter species; the remaining 10% of respondents preferred not to answer this question. Remarkably, 15% of respondents reported changes in the weather, referring to less rainfall, and hence less water in the rivers and their tributaries, especially in the drier months, which

FIGURE 3 Smooth-coated otters recorded from the study sites (Photo: Ritesh Suri)

TABLE 1 Number and percentage of positive sites of otter activity along sampled reaches of the four rivers

River	Length of river sampled (km)	No. of sites surveyed	Positive sites	Percentage (%)
Kosi	35	88	3	3.4
Ramganga	25	63	10	15.9
Khoh	22	55	4	7.3
Song	21	53	0	0.0

could have affected otter populations. These observations are supported by published literature (Alfthan et al., 2018).

4.3 | Otter conservation education programmes

The otter conservation education programmes (Figure 4) assisted in securing the involvement of local community members in setting up a community-based conservation initiative (CBCI) to monitor and report otter sightings from the area. This was extremely helpful, yielding immediate results, with photographs of observed otter footprints and latrines subsequently sent by CBCI members to the research team.

Additional strategies to enhance the sustainability of the CBCI will be a key focus of a planned second phase of field research.

4.4 | Habitat suitability mapping for otters

Figure 5 shows the LULC maps of the rivers, comprising six major land-use classes. Accuracy assessment was also performed by ground-truthing to evaluate the quality of the LULC maps. Quality control assessments of the LULC maps based on field observations indicated 90% accuracy (see Supporting Information).

The LULC data showed that the Ramganga (64%) and Khoh (45%) rivers had the highest percentage of forest cover. This is not surprising, as these rivers are located between protected areas in Uttarakhand. Agricultural area was highest along the Song (29%) and Khoh (19%) rivers. This may have contributed to the failure to detect otters in the Song River, as settlements were also recorded to be

FIGURE 4 Banner and flyers used for enhancing community awareness among local stakeholders for otters and the associated benefits in the region

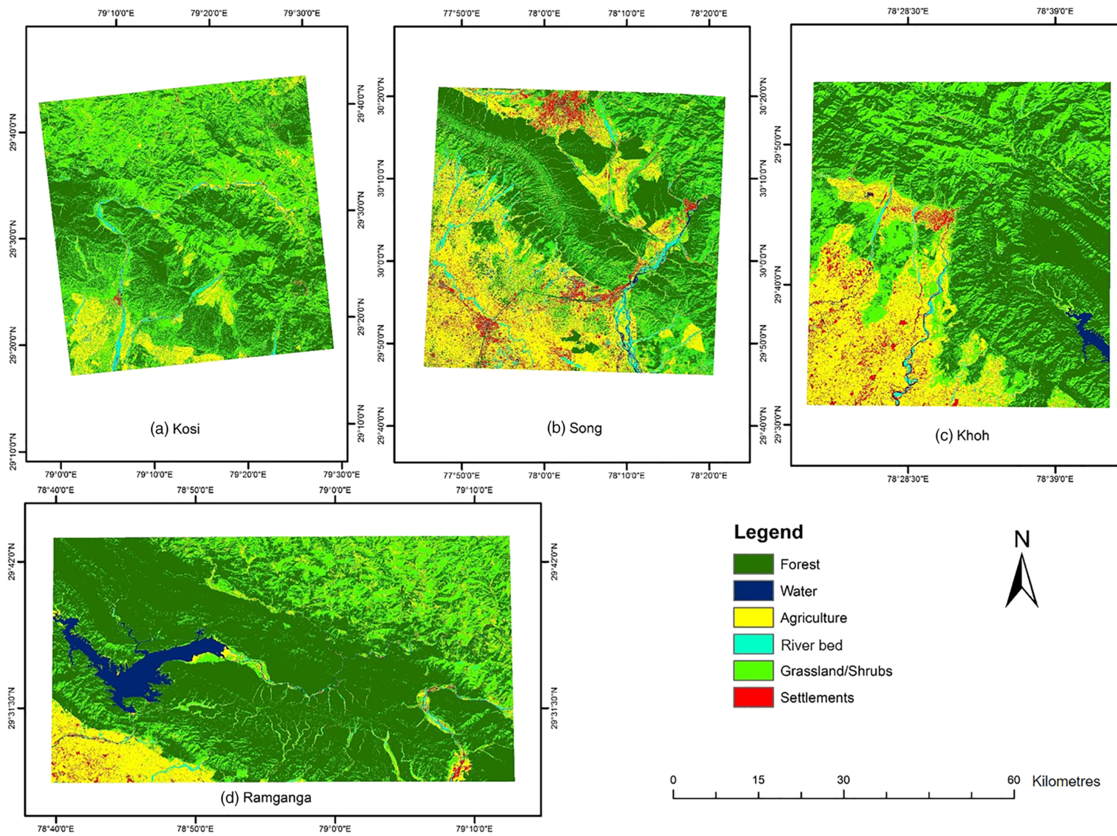

FIGURE 5 Land cover classification of (a) Kosi, (b) Song, (c) Khoh, and (d) Ramganga rivers

highest here (6.5%), compared with the other three rivers. Grassland/shrubs were highest in the Kosi River (43.6%), followed by the Khoh River (28%) (Figure 6).

Habitat suitability maps for the rivers studied are presented in Figure 7, with areas of suitability shown in Figure 8. The habitat suitability maps were validated with field observations (ground control points and field photographs) of otter sightings.

The Kosi River had the highest percentage of high-suitability area (20.34%), followed by the Khoh with 11.73%. The Song River had the lowest percentage of high-suitability area (3.82%). Where positive field observations of otters were recorded, these coincided with river reaches within the high-suitability category in all rivers surveyed. The Khoh River had the highest percentage (46.79%) of moderately suitable area.

The Song River had the highest percentage of low-suitability area (61.66%). Only 1.26%, 0.87%, 0.73%, and 0.82% of the lengths of the Kosi, Western Ramganga, Song, and Khoh rivers respectively were recorded as unsuitable.

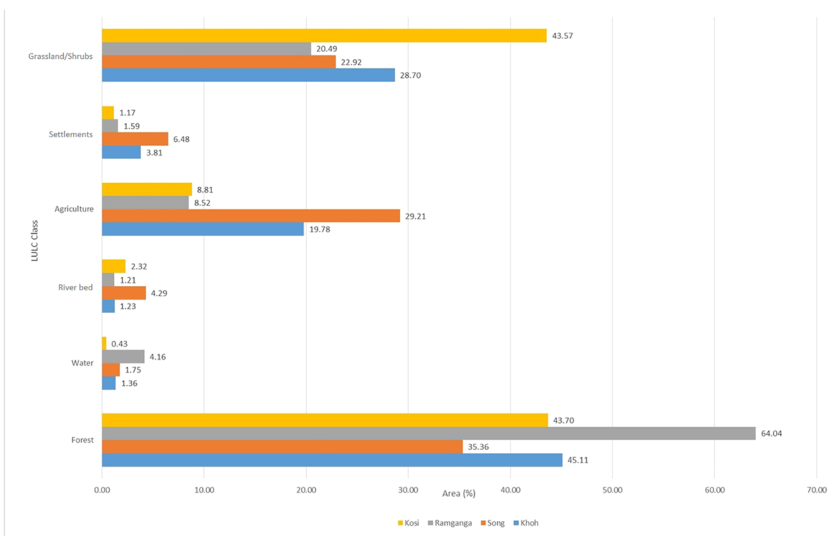

FIGURE 6 Land use land cover (%) for the Kosi, Ramganga, Song, and Khoh rivers

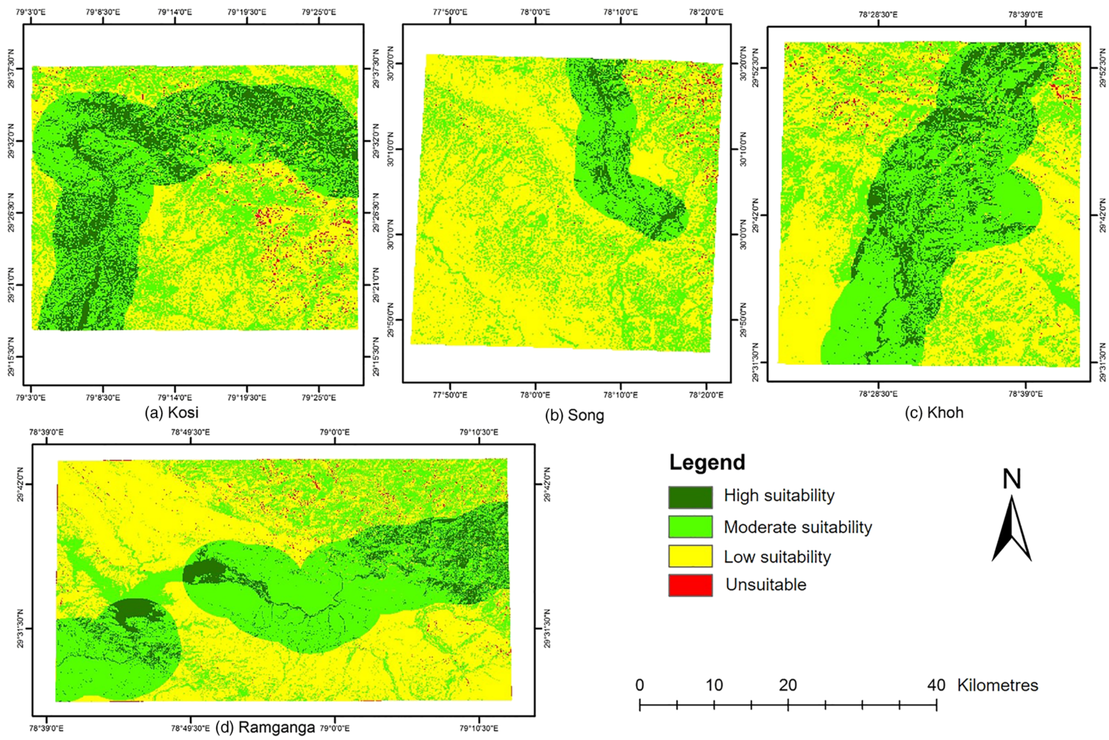

FIGURE 7 Habitat suitability maps for otters in the study sites: (a) Kosi, (b) Song, (c) Khoh, and (d) Ramganga rivers

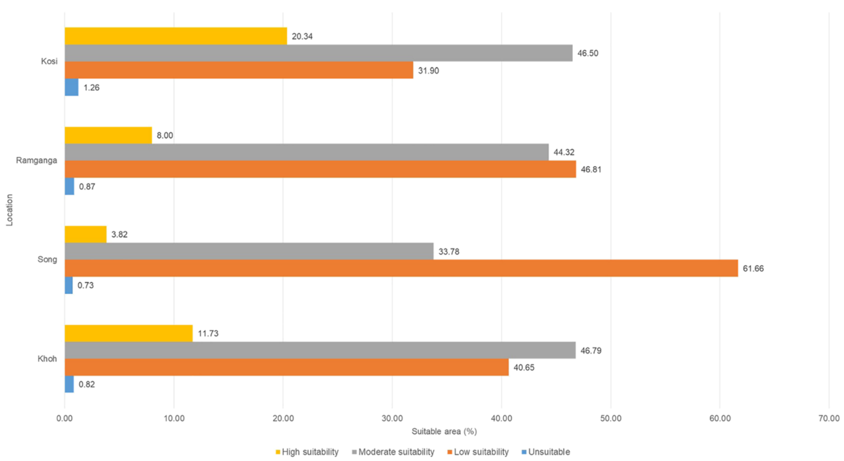

FIGURE 8 Habitat suitability areas for otters in the study sites: (a) Kosi, (b) Ramganga, (c) Song, and (d) Khoh rivers

5 | DISCUSSION

The only otter species directly identified in the study areas was the smooth-coated otter. Eurasian and small-clawed otters were not observed during this study. However, absence of otter signs in a particular place does not necessarily mean the absence of otters in that area (Hussain & Choudhury, 1997). Furthermore, some indirect signs are not specific to any of the three otter species. To address greater specificity of otter species identification, the authors plan to place camera traps at otter latrines to detect otter presence in a follow-on study as an additional approach for monitoring the proportion of each species in riparian areas. One option being explored for regular data retrieval and protection of camera trap equipment is replication of the 'goatwala for tigerwala' model developed for monitoring tigers and other wildlife by the non-governmental organization Tiger Watch. This involves engaging local volunteers (many of them local goat grazers or 'goatwala') to collect and transmit data, and also subsequently to serve as community activists promoting wildlife conservation ('tigerwalas') (Everard, Khandal, & Sahu, 2017).

Although not entirely reliable, the semi-structured questionnaire used in the social science surveys provided a time-saving, cost-effective, and systematic way to gather information from a target population (Gupta et al., 2014). Semi-structured interviews showed that, although local communities were aware of their presence, very few had actually seen otters in the wild. There was a need, as expressed by one respondent, to '… see with our own eyes what you want us to protect'.

Identification of habitat suitability areas for otters outside protected areas in the four rivers surveyed is an important finding. It may be possible to use a combination of high- and moderate-suitability areas in the four river reaches surveyed — Kosi (66.84%), Ramganga (52.32%), Song (37.60%), and Khoh (58.52%) — to formulate a targeted, species-specific conservation plan for the region (Gupta et al., 2016).

The weighted linear modelling approach integrated diverse variables influencing habitat suitability for otters, taking account of species-specific factors, temporal, spatial, and budgetary limitations of field surveys, and available expert and local knowledge. The four most important primitive variables identified for otter species and used in developing habitat suitability maps were land cover, elevation, slope, and distance from the river. These variables were weighted equally to develop an HSI. It is recognized, however, that supplementary variables, such as the important factor of prey availability (Sales-Luís, Pedroso, & Santos-Reisa, 2007) and consideration of the diet and feeding behaviour of otters (Lanszki, Lehoczky, Kotze, & Somers, 2016), as well as pollution and climatic indicators, should be taken into account in future to refine suitability maps, and thereby to better support conservation initiatives. The study area has varying topography. In flat terrain (less topographic variation), topographic variables such as slope are less important than land cover and distance from the river, so an equally weighted linear modelling approach may not optimally represent true ecology of the otters; hence, it is not appropriate for developing suitability maps. This may also need to be taken into account in future refinements of the method.

Furthermore, by 2050, mean temperature across the IHR is projected to increase by 1–2°C relative to a 1960s baseline; the monsoon is expected to become longer and less predictable; precipitation is projected to vary by 5% on average; and the intensity of extreme rainfall events is likely to increase (Alfthan et al., 2018; Shrestha et al., 2015). In addition, glacial mass-balance modelling based on climate projections to 2030, 2050, and 2100 indicates substantial losses in glacial mass and area in the coming decades for most parts of the IHR (Indian Network for Climate Change Assessment, 2010), which will affect river discharge and other properties (Alfthan et al., 2018). The selected rivers are also the prime habitat for many other small mammals, such as the fishing cat (*Prionailurus viverrinus*), mugger crocodile (*Crocodylus palustris*), gharial (*Gavialis gangeticus*), and a diversity of resident and migratory birds (NG, unpublished data). Conservation measures for otters, as 'flagship' species (Verissimo, MacMillan, & Smith, 2010), are also therefore likely to yield conservation benefits for these other taxa and the overall integrity, functioning, and ecosystem service provision of these rivers.

A critical finding from the region has been the detection of smooth-coated otters from river reaches outside protected areas. Given the important role being played by the Corbett and Rajaji Tiger Reserves in safeguarding threatened species within their boundaries (Gupta et al., 2015) but a proliferation of pressures outside of them, it is vital for conservation strategies also to target these 'unprotected areas' (Gupta et al., 2015) to maintain linear connectivity between otter habitats. Given existing and intensifying land use in the region, and the diminishing habitat available for otters and other riverine species, it is critical also to protect these areas through targeted and sustainable measures in the study area.

There is a further need to ensure regular monitoring of existing otter habitats by strengthening the capacities of local community members to help generate a database of the population status of otters. Engagement of local people in identification with their local wildlife and its conservation is significant, as the biodiversity and ecosystem services of 'cultural landscapes' are shaped by human management (Antrop, 2004; Schaich, Bieling, & Plieninger, 2010). The otter conservation education programmes conducted during this study resulted in a proposal to set up a CBCI to monitor and report otter sightings from the area. Civil society engagement approaches of this type can potentially represent a way forward for achieving simultaneous community-based otter conservation and associated ecosystem benefits for local communities (Everard et al., 2017; Gupta, 2013). Providing this critical information to decision-makers in influential bodies, at national and international levels, will help to promote the development of an otter conservation programme for Uttarakhand and other similar regions.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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